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TECHNICAL MEMORANDUM

No. 1119

SYSTEMATIC WIND-TUNNEL MEASUREMENTS ON A LAMINAR WING WITH NOSE FLAP

By W. Krueger

Translation

Systematische Windkanalmessungen an einem Laminarflügel mit Nasenklappe

Forschungsbericht Nr. 1948

Washington

April 1947

(NASA-TM-79870) SYSTEMATIC WIND-TUNNEL MEASUREMENTS ON A LAMINAR WING WITH NOSE FLAP (National Advisory Committee for Aeronautics) 18 p

N78-78538

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By W. Krueger

ABSTRACT: Results of measurements are given as a supplement to earlier tests for a laminar profile with nose flap; magnitude, form, and angle of attack of the flap were systematically changed. The experiments were carried out at an effective Reynolds number of 8.2×10^5. The maximum lift was increased to an optimum of $\Delta c_{a_{max}} \approx 0.7$. A comparison with measurements on other profiles shows that the effect of a nose flap is essentially dependent upon magnitude of the nose radius coefficient $\frac{\rho l}{(d/l)^2}$ of the profile.

OUTLINE:

I. Introduction

II. Description of the Model and Experimental Arrangements

III. Definitions and Measured Results

IV. Summary and Deductions

V. Bibliography

I. INTRODUCTION

A report was made earlier on the first tests on a wing with nose flap (1). It was pointed out already that the lift increasing effect of the nose flap can be of particular importance for distinct high-speed flight profiles with very pointed nose. The beneficial

*"Systematische Windkanalmessungen an einem Laminarflügel mit Nasenklappe," Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters (ZWB) Berlin-Adlershof, Forschungsbericht Nr. 1948, Göttingen, den 13.6.44.

effect of the nose flap was confirmed by an adjoining test on the Russian laminar profile 2315 Bis (2). The influence on the maximum lift of magnitude and form of the nose flap was recognizable from the results of the preliminary tests. These influences were systematically investigated in the present measurement. First of all, the modifications of the aerodynamic coefficients of the wing during the extending of the flap had to be elucidated.

II. DESCRIPTION OF THE MODEL AND EXPERIMENTAL ARRANGEMENTS

The test wing was rectangular and showed the following design dimensions:

Span	$b = 1.23m$
Chord	$l = 0.25m$
Reference area	$F = 0.3065m^2$
Aspect ratio	$\Lambda = 4.94$

The wing tips were formed according to recent test results (3) (cross section of the wing tip ahead of the point of greatest thickness semicircular, behind it elliptic). The form of the Russian laminar profile 2315 Bis that was used can be seen in figure 1. The nose flaps were fastened to the wing by means of a piano hinge whose axis of rotation was at the curvature center of the nose of the profile. Thereby a quick exchange of the flaps and an uninterrupted modification of the flap angle were made possible. Apart from the nose flap, the profile could be furnished with a split flap of 20 percent chord. The measurements were carried out in tunnel 1 of the AVA ($2.24m\phi$, $F_o = 4.0m^2$).

III. DEFINITIONS AND MEASURED RESULTS

The definitions of the force and moment coefficients as well as their sense of direction conform with the norm DIN L 100. All coefficients are referred to the area (inclusive of the wing tips) and to the chord of the smooth profile, respectively. The transverse axis situated in $l/4$ is the axis of reference for the longitudinal moment. The measurements were generally carried out at a Reynolds number of 7.2×10^5 (wind velocity 40 m/s). Taking the degree of turbulence of the air flow into consideration (factor of turbulence 1.13) the effective Re-number is 8.2×10^5. The test results were

in the usual manner expressed in terms of infinite free jet cross section and infinite aspect ratio. The forms of nose flaps which were investigated are put side by side for a better survey in figure 2. The systematic variation of the chord, camber and leading-edge curvature of the flap were examined as well as the influence of a slot between wing and flap. The best flap angle for each case had to be ascertained.

The results of the three-component measurements are represented in the figures 3 to 12 following a few comments.

Influence of the nose-flap angle.- The maximum lift is to a very high degree dependent upon the flap angle as had become evident before. Figure 3 shows the maximum lift increment $\Delta c_{a_{max_N}}$ by the nose flap as a function of the angle η_N for the wing with and without rear split flap and various chord ratios of the nose flap. Below $\eta_N \approx 100^\circ$, $c_{a_{max}}$ deteriorates, beyond that figure it improves. Nearly all optimum values according to the present measurement are at $\eta_N = 130^\circ + 140^\circ$ as constrasted with earlier measurements on the same profile (2), where the most favorable angle was at around $\eta_N = 113^\circ$. This result was checked several times and was confirmed time and again for other wind velocities as well as with turbulence screen (turbulence factor 2.03).

Influence of the chord ratio.- The results with three nose flaps of chord ratios of $l_N/l = 0.05$; 0.10 and 0.20 are represented in figure 4. One can see that $c_{a_{max}}$ increases considerably with increasing chord ratio. The curves for each case are given for the most favorable angle η_N. Moreover, the curve $c_a = f(\alpha_\infty)$ for an angle $\eta_N = 140^\circ$ which is less then the optimum value is graphically represented for the flap of the chord ratio $l_N/l = 0.2$. A surprisingly flat maximum is obtained for this case. Even for an α of 28° (that is, $\alpha \approx 32^\circ$ at $\Lambda = 6$) $c_{a_{max}}$ is still larger by an amount of 0.58 as contrasted with the smooth profile. An observation of the flow with smoke demonstrated that in this case separation occurred shortly behind the transition point from the nose flap to the wing. Consequently the flap must have big loading.

Figure 5 shows the gain in maximum lift by the effect of the nose flap as a function of the flap-chord ratio for various curvatures (δ/l) of the leading edge. The increment which was obtained with the small nose flap of $l_N/l = 0.05$ at the greatest curvature of the leading edge makes the use as a means of stall control seem successful.

Behavior in separation.- Flow observation by means of tufts on the wing without a split flap produced reliable proof that on a wing with a nose flap the turbulent point of separation travels slowly forward from the trailing edge of the wing with increasing angle of attack while the smooth wing separates very suddenly near the nose of the profile. This phenomenon indicates that the pressure increase is diminished considerably by the nose flap after flowing around the nose of the profile; this fact altogether explains the increase of the maximum lift. A similar effect could be observed for the wing with split flap; however, the separation occurred here more suddenly than without split flap even when a nose flap was provided.

Influence of the leading-edge curvature.- A further increase of the maximum lift can be made possible by increasing the curvature of the leading edge of the flap, as evidenced by figures 6 and 7. The course $c_{a_{max}} = f(\delta/l_N)$ for $l_N/l = 0.1$ (fig. 7) shows for a very great curvature a decrease of $c_{a_{max}}$. This phenomenon might perhaps be elucidated later by pressure-distribution measurements and calculations.

Influence of the camber of the flap.- The camber of the flap had been selected for most of the investigations particularly so that the surface of the flap when the latter was extended coincided with the contour of the pressure side of the smooth profile. Beside this normal camber, $(f_N/l_N = 0.095)$, the cases $f_N/l_N = 0$ and 0.16 were measured on the nose flap of 10 percent chord in order to determine the influence of the magnitude of the camber. The results are shown in figure 8. One can see that no essential improvements can be obtained by an increase of camber.

Modification of the aerodynamic coefficients during the extension.- The coefficients c_a, c_w, c_M as a function of angle of attack and nose-flap angle must necessarily be known in order to judge the flight behaviour of an airplane which is equipped with a nose flap. These values are represented for the chord ratio $l_N/l = 0.05$ and 0.10 in figures 9 and 10. The coefficients for the wing without nose flap also are contained in the graphs. The modifications of c_a (at unchanged α) and of the coefficients c_w and c_M (at unchanged c_a) in the interesting region of original conditions which are caused by the extension of the nose flap, as contrasted with the starting condition "no nose-flap extension," are rather small when compared to the modification that occur, for instance, by the extension of a rear split flap. This statement is valid in particular for the case of the nose flap of a chord ratio $l_N/l = 0.05$ and also for the case that the split flap was extended before the nose flap. There is only

one basic difference as contrasted with the extending of a split flap: the extending of a nose flap causes the drag to increase and simultaneously the lift somewhat to decrease while the extending of a split flap causes an increase in the drag and also of the lift. Since, however, the decrease of lift which first occurs for small nose-flap extensions is small, this difficulty may be assumed to be not unsurmountable. The flight properties can probably be rendered normal by an appropriate combination of the extension of nose and split flaps. Also, a purposive selection of the extending velocity can probably overcome possible contingent difficulties since for the unsteady phenomenon a temporal delay until the new flow condition is formed is surely to be expected. Tests for the water channel are being prepared in order to judge these questions; in these tests the flow phenomena for extending velocities of various magnitudes will be observed.

High extending velocities coupled with small power requirements for extension could certainly be obtained by an aerodynamic balance of the flap moments. Such balance could for instance be arrived at by an appropriate coupling of the nose-flap extension with a split-flap extension in the rear region of the profile. If for this purpose the split flap is arranged so that the extended flap lies ahead of its axis of rotation, its sense of rotation therefore is opposed to the usual one, the split flap will automatically be extended further by the moment of the air force which appears when the flap is extended from its zero position. The moment of the air force of the split flap could be used for a total or partial balance of the moment of the nose flap; this aim could be reached by an appropriate selection of the area ratio nose flap/spit flap.

Influence of the slot.- Figure 11 shows that the lift increasing effect for a nose flap of a chord ratio $t_N/t = 0.10$ is nullified by a slot between wing and flap. The corresponding curves $c_a = f(\alpha_c)$ for the case "without slot" are drawn in dashed lines into the graph for comparison. A flow through the slot from the pressure side to the suction side has in this case a disturbing effect.

Comparison of the effects of nose flaps for various forms of profile.- Besides the present investigation and the reports mentioned in paragraph V a measurement on the profile "Mustang-Walz 2" with nose flap was carried out in the meantime; this test will be published soon at the ZWB. Moreover an experiment on a nose-flap profile with normal nose radius was carried out by the firm Messerschmitt A.G. according to a suggestion of the AVA (4). The profiles which were investigated, the main data

on their construction and the lift increases that were obtained by the nose flap are represented in figure 12. It was to be expected that the lift increasing effect of the nose flap would be greater the more pointed the profile used. The plot of the gain in $c_{a_{max}}$ by the nose flap versus the nose-radius coefficient $\frac{\rho/l}{(d/l)^2}$ (fig. 12) confirms this assumption very well. The comparison is not quite unobjectionable because the Re-number was not the same for all tests; but one may suppose that the trend of the curves would not change essentially at the same Re-number.

VI. SUMMARY AND DEDUCTIONS

Measurement results for the Russian laminar profile 2315 Bis with nose flap are given where form, magnitude, and angle of attack of the flap had been changed systematically. The lift increase by the nose flap amounts, in the most favorable case, to about 0.7. The most favorable flap angle, measured with repect to the wing chord is between 130° and 140°. The greater the flap chord ratio and the camber of the flap the stronger is the effect. The relatively good results which were obtained by a flap of 5 percent chord and large rounding-off radius of the leading edge make the use of the flap as a means of side slip prevention seem promising. The modifications of the aerodynamic coefficients during the extending of a nose flap are smaller than the ones originating when extending normal split flaps. Therefore it may be assumed that the flight properties can be influenced favorably, particularly so when nose and split flap or camber flap, respectively, are combined appropriately. A slot between nose flap and wing has an unfavorable effect. A comparison of the effects of nose flaps on various profiles shows a marked increase of effect with decreasing nose-radius coefficient $\frac{\rho/l}{(d/l)^2}$. Consequently $c_{a_{max}}$ can be improved essentially by nose flaps only for profiles here the turbulent separation occurs, because of a very rapid pressure increase, in the flow immediately behind the nose of the profile. The large negative pressure near the nose can be considerably decreased by the nose flap; the behaviour in separation of such profiles can be made similar to the behaviour of profiles with normal nose-radius coefficients.

Translated by Mary L. Mahler
National Advisory Committee
for Aeronautics

V. BIBLIOGRAPHY

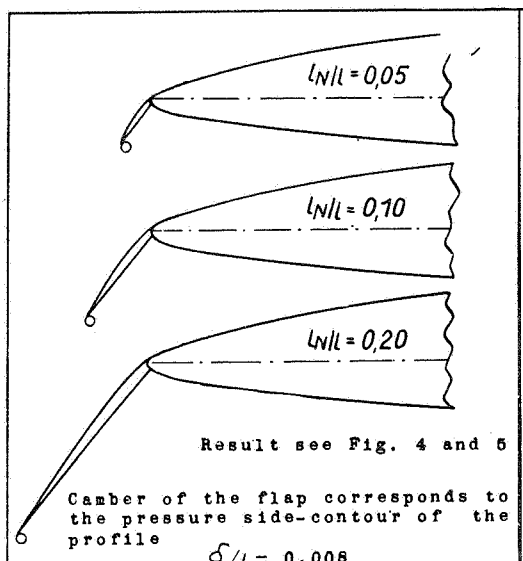
1. W. Kruger, Ueber eine neue Möglichkeit der Steigerung des Hochstauftriebes von Hochgeschwindigkeitsprofilen. U.u. M.3049.

2. F. Riegels, Russische Laminarprofile. 3. Teil: Messungen am Profil 2315 Bis mit AVA-Nasenklappe. U.u.M. 3067.

3. B. Regenscheit, Untersuchungen über den Einfluss der Randkappenform auf die Tragflügelmessergebnisse. Erscheint demnächst in den "Technischen Berichten".

4. Ehrhardt, Windkanaluntersuchungen mit einer Nasenklappe Windkanalbericht 7/44 Messerschmitt A.G.

Figure 1. The test profile 2315 Bis.

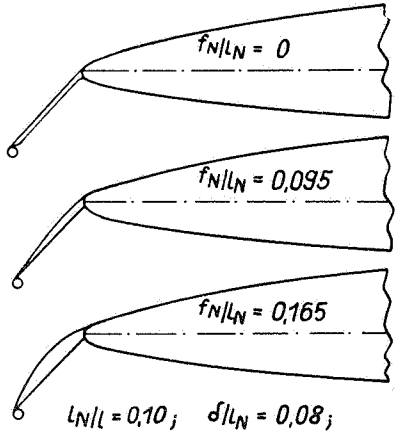


Result see Fig. 4 and 5

Camber of the flap corresponds to the pressure side-contour of the profile

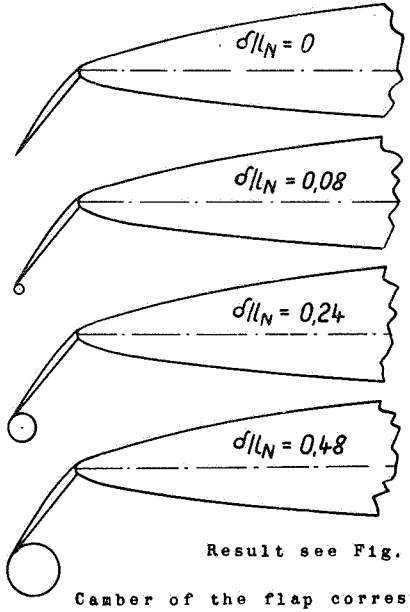
$\delta/l = 0.008$

Influence of the chord of the Nose flap



Result see Fig. 8

Influence of the camber

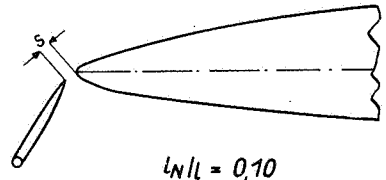


Result see Fig. 6 and 7

Camber of the flap corresponds to the pressure side-contour of the profile

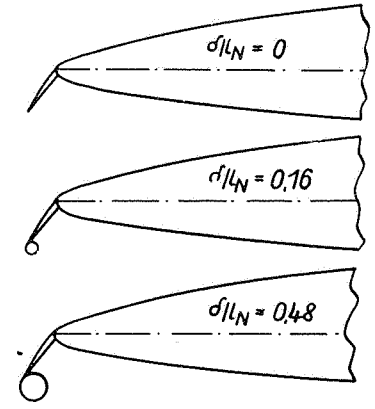
$l_N/l = 0.10$

Influence of the curvature of the leading edge



Result see Fig. 11

Influence of a slot



Result see Fig. 6 and 7

Camber of the flap corresponds to the pressure side-contour of the profile

$l_N/l = 0.05$

Influence of the curvature of the leading edge

The total profile chord for the graphs is: $l = 250$mm

Scale: $\frac{\text{Graph}}{\text{Model}} = 1:1$

Figure 2. The forms of nose flaps which were investigated.

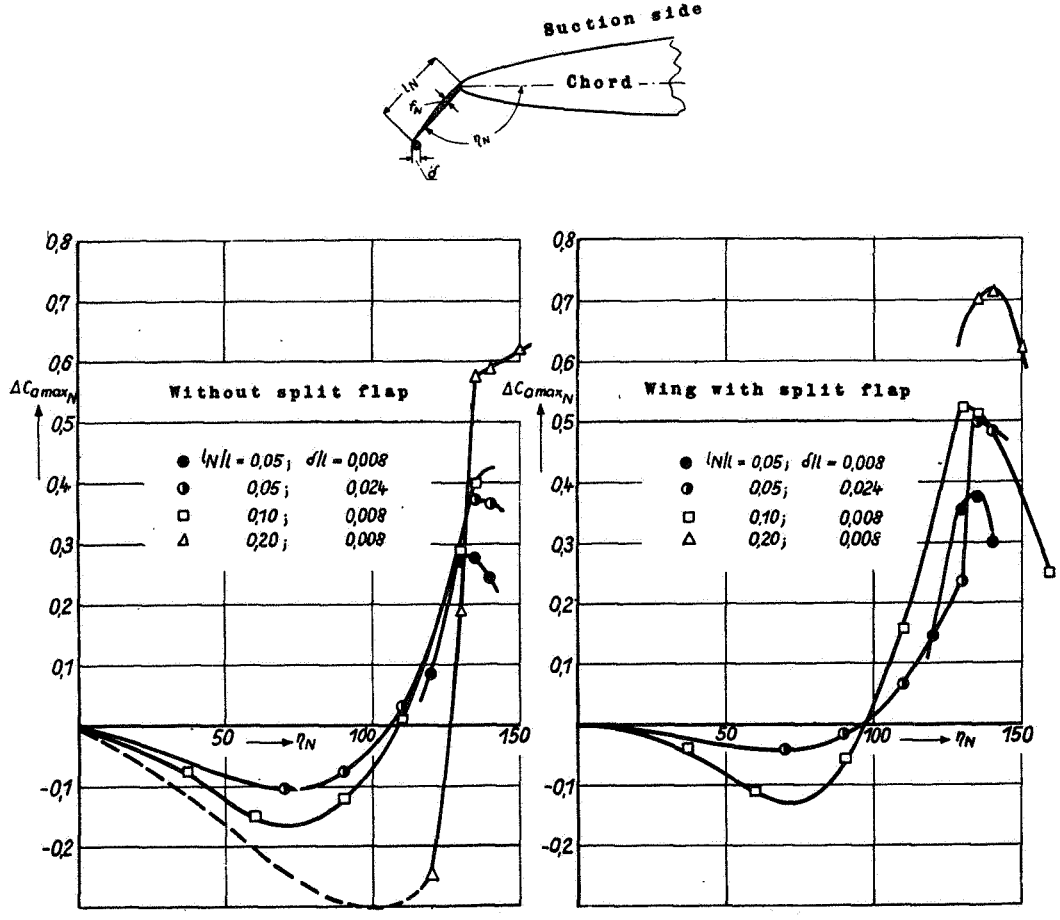


Figure 3. Increase of the maximum lift coefficient by the effect of the nose flap as a function of the angle of deflection η_N. Parameter: nose flap chord ratio (l_N/l) and curvature of the leading edge (d/l). The camber of the nose flap corresponds to the pressure side contour of the smooth profile.

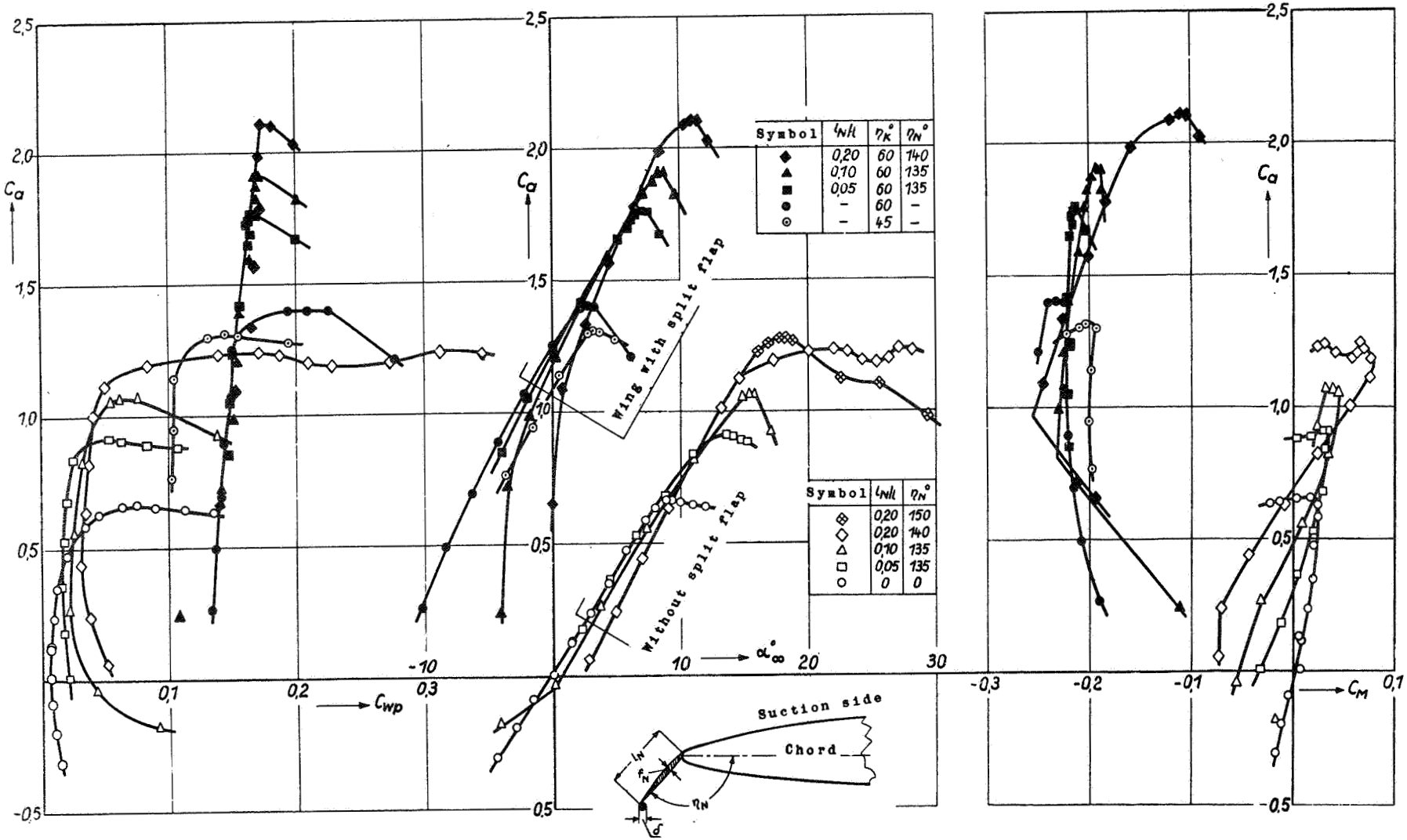


Figure 4. Influence of the chord of the nose flap upon the aerodynamic coefficients of the wing with and without split flap. Valid for the most favorable nose flap angle η_N and for $\delta / l = 0.008$. The camber of the nose flap is selected so that it coincides with the pressure side contour of the smooth profile when the flap is extended.

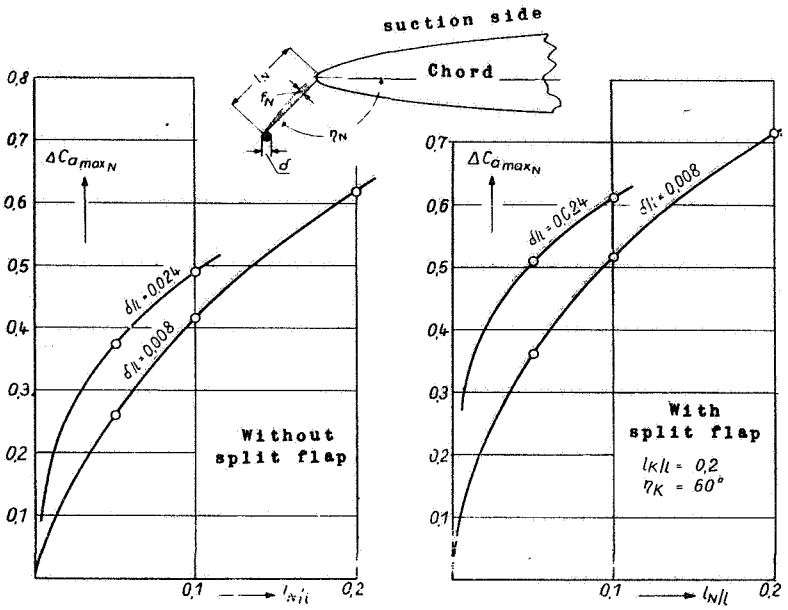


Figure 5. Increase of $c_{a\ max}$ that was obtained by the nose flap as a function of the nose flap chord ratio, Parameter: δ/l. The camber of the nose flap corresponds to the pressure side contour of the smooth profile.

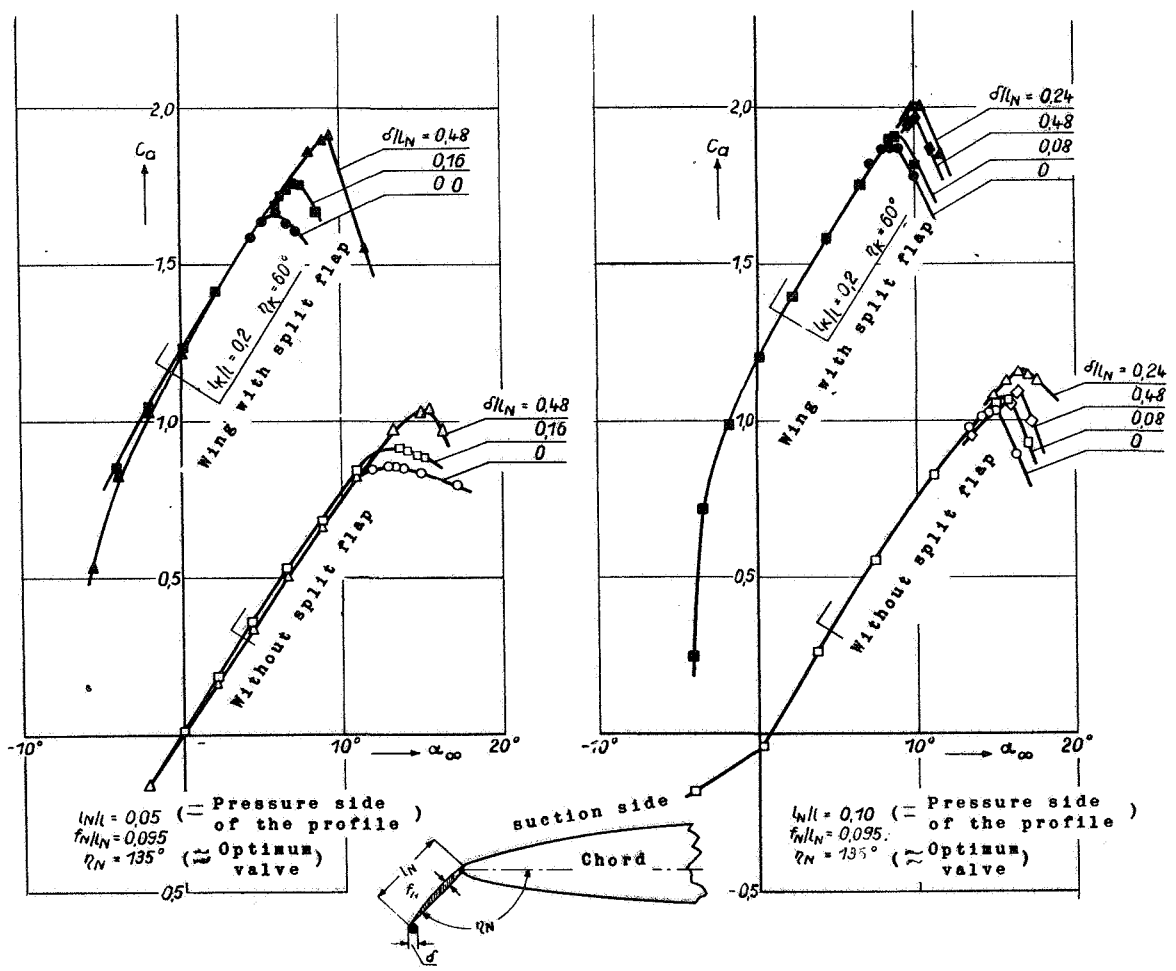


Figure 6. Influence of the curvature at the leading edge of the nose flap upon the lift.

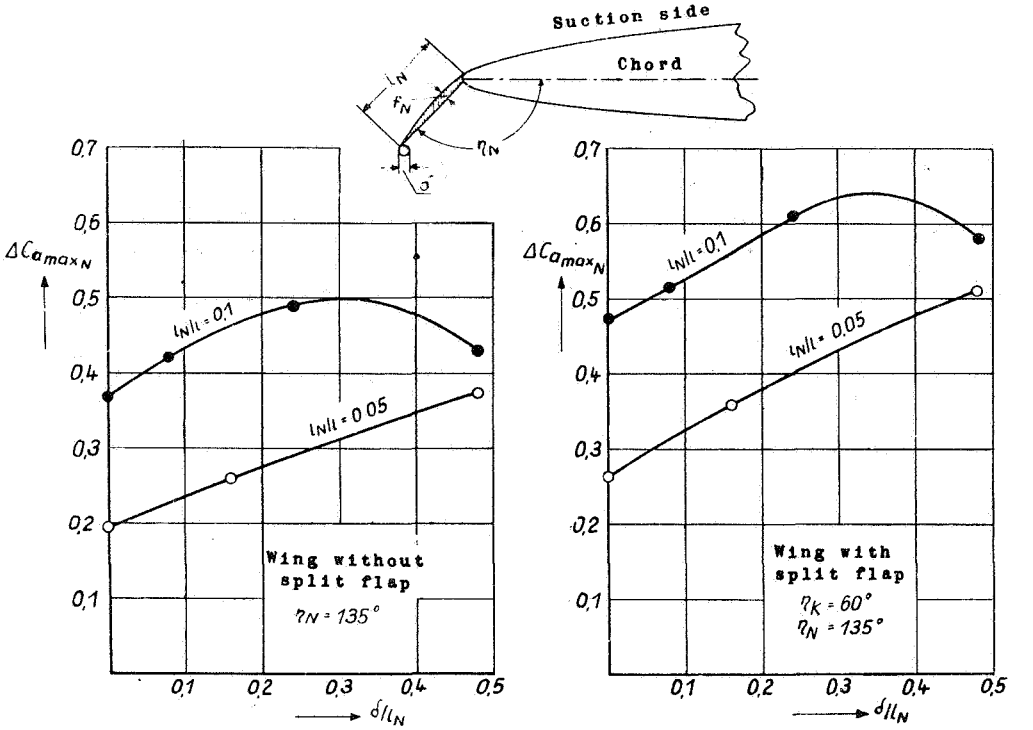


Figure 7. Increase of $c_{a\ max}$ which was obtained by the nose flap as a function of the curvature of the leading edge of the flap. Parameter: flap chord ratio l_N/l.

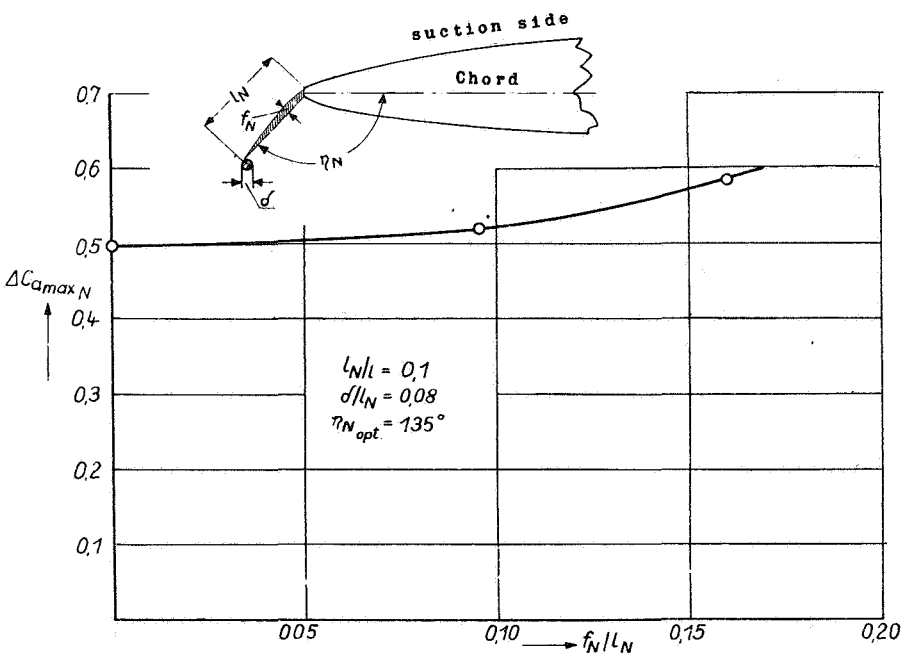


Figure 8. Increase of $c_{a\ max}$ which was obtained by the nose flap as a function of the flap camber (f_N/l_N). Wing with split flap (l_K/l = 0.2; η_K 60°). For f_N/l_N = 0.095 the camber of the nose flap corresponds to the pressure side contour of the smooth profile.

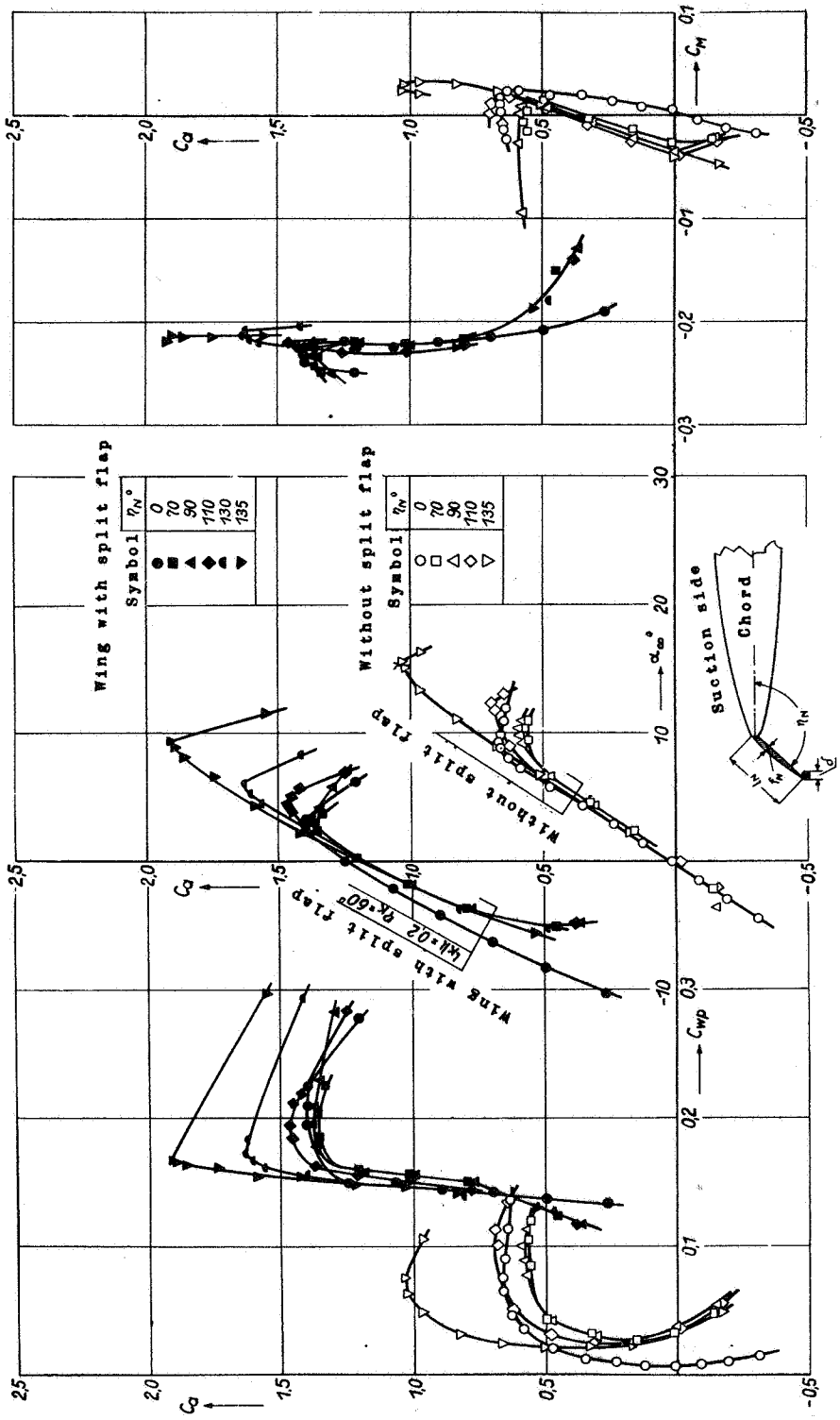


Figure 9. Aerodynamic coefficients as a function of the flap angle η_N. (Modifications during the extension from $\eta_N = 0$ to $\eta_N = \eta_{N\ opt.}$). valid for: $l_N/l = 0.05$
$f_N/l_N = 0.095$ (= suction side of the profile)
$\delta/l_N = 0.48$

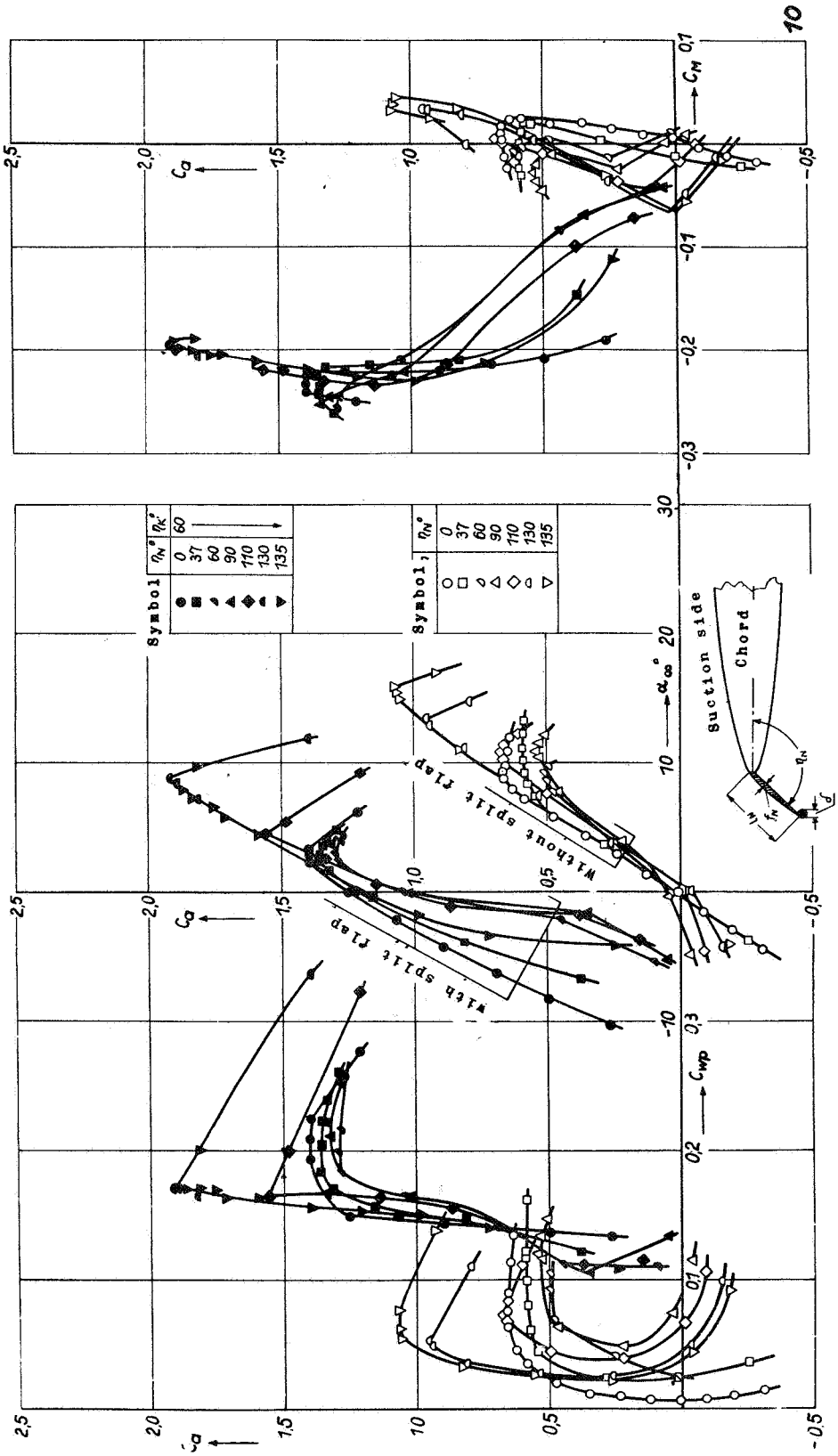


Figure 10. Aerodynamic coefficients as a function of the flap angle η_N. (Modifications during the extension from $\eta_N = 0$ to $\eta_N = \eta_N$ opt.). valid for: $t_N/l = 0.10$
$f_N/l_N = 0.095$ (= pressure side) of the profile
$\delta/l_N = 0.08$

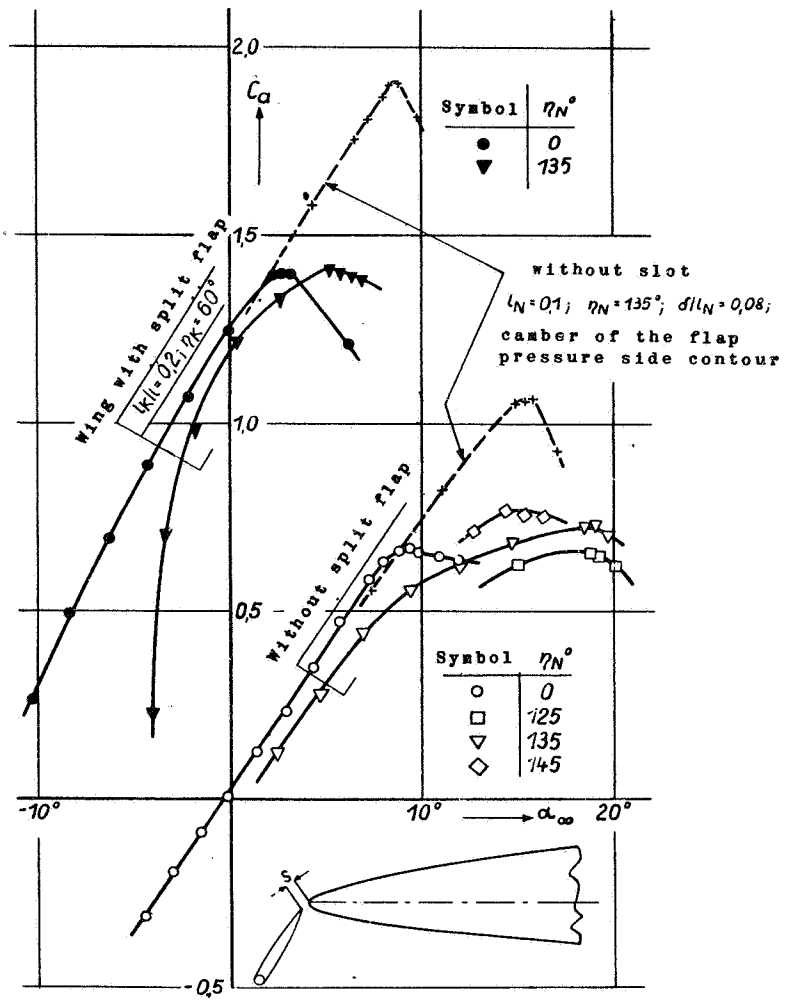


Figure 11. $c_a = f(\alpha_\infty)$ for the wing with nose flap and slot. The case " without slot " is indicated by a dashed line for comparison.
$l_N/l = 0.1$ $\delta/l_N = 0.12$ $s/l = 0.01$

	d/l	f/l	$x_{d/l}$	$x_{f/l}$	$\frac{\varrho/l}{(d/l)^2}$	l_N/l	d/l_N
2315 Bis — Present report and U.u.M. 3067	0,12	0,01	0,50	0,50	0,210	0,10	0,24
Mustang-Walz 4 (UuM 3049)	0,15	0,015	0,60	0,25	0,3625	0,10	0,30
Mustang-Walz 2 (Test AVA. will be published soon)	0,136	0,02	0,39	0,25	0,626	0,10	0,167
Messerschmitt-Profile (Drop: NACA 0 0012 - 1,1 - 30) (Report WK 7/44)	0,12	0,04	0,30	0,30	1,10	0,10	≈ 0,05

(Mean camber line = Glavert S-shaped mean-camber line with 4% chord)

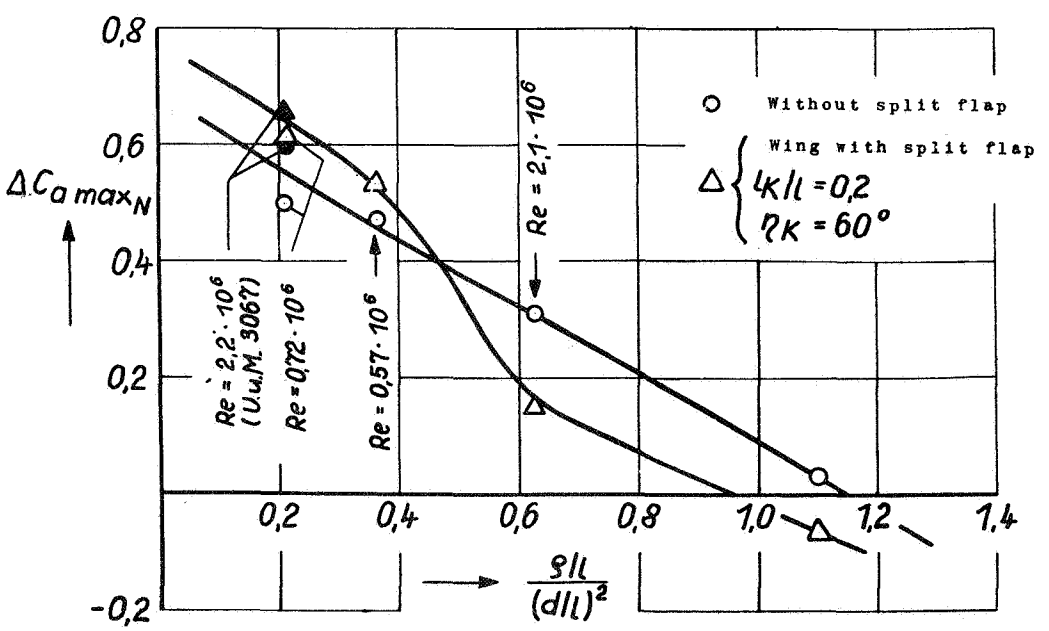


Figure 12. Effectiveness of the nose flap for various profiles. Increase of the lift by the nose flap $\Delta\, c_{a\,max_N}$ as a function of the nose radius coefficient $\frac{\varrho/l}{(d/l)^2}$.